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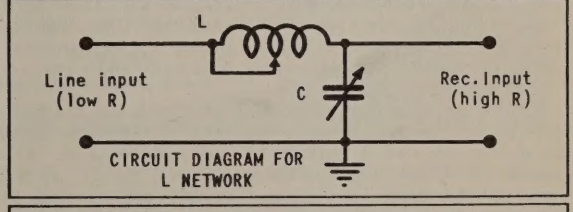
RECEIVER-TO-LINE MATCHING NETWORKS

By Clayton F. Bane, W6WB

It is reasonably safe to state that the performance of most receivers used in amateur stations can be substantially improved by the simple expedient of transforming the impedance of the transmission line from the antenna to the input impedance of the receiver. While this generalization applies more to some receivers than to others, proper matching can improve the weak-signal performance of almost any of them particularly when low impedance lines, (50/72Ω) are in use. It is difficult to achieve a relatively constant input impedance in a receiver that is to cover a substantial frequency range since the L/C ratio in the input circuits must vary widely between band-edge limits. For this reason, (among others) the input impedance of a receiver is generally rated on an average basis --an actual plot over the particular range in in use will probably show very marked high and low departures from this average value. There is really no way to know what the exact input impedance may be unless it is actually measured at points within each band. Some years ago this would have been a laboratory job calling for a good impedance bridge but today there are some simple gadgets that can be home-built that tell the complete story. The "Antennascope" described in CQ for September 1950 will do it--the simple co-ax SWR bridge will do it equally well.

Many of us have had the impression from time to time that our receivers sounded a bit dull even though we were using a good beam antenna. Any modern receiver with two pre-RF stages should have greater potential gain than it is possible to use. Since after all, the limiting factor is the internal and external back ground noise, there is little point in piling on more gain if the background noise rises in proportion. One of the popular modern receivers uses but a single high-gain 6AK5 RF stage yet is capable of outstanding performance provided a bad mis-match does not exist between line and receiver. It is highly probable that such mismatch does exist in many makes of receivers particularly when low impedance lines are used. Obviously, impedance-matching pre-RF units such as the R9'er can be used ahead of the receiver but these introduce another tube which contributes to the inherent set noise. The increased pickup of a properly matched receiver can be quite surprising--in the writers set, better than one full "S" point average on all bands with one band showing a three "S" point rise! Gain achieved in this manner is all on the good side--the strength of the incoming signal is increased but the internal set noise remains constant. Surely this is worth the small amount of trouble involved in setting up such a match. The procedure to follow assumes that a co-ax bridge will be used for measurement.

It will first be necessary to provide an RF driving source for the co-ax bridge. This can conveniently be any low-powered exciter, the only stipulation being that it have some adjustable means for varying its output. The initial set-up procedure is identical to that employed in measuring SWR on a line. The bridge is coupled to the driving source with a random length of co-ax; the bridge being terminated in a short section of line having the same impedance. The meter in the bridge is set for full-scale deflection by varying the RF driving source coupling. Incidentally, one need have no concern about damage to the receiver input circuits since the power necessary to provide a full-scale reading on a 0-1 ma meter is quite small indeed.



CIRCUIT DIAGRAM FOR L NETWORK

DESIGN CONSTANTS FOR L NETWORKS

R-Line	R-Rec.	X_c	X_L	L	C
52	100	103.7	50	.56	108
"	200	116	87.6	.98	97.3
"	300	132	113.5	1.2	85.5
"	400	152	134.5	1.5	74.2
"	500	166	153.5	1.73	68
"	600	181.8	170	1.9	62
"	800	208	196	2.2	54
"	1000	232	222	2.5	48.6
"	1500	280.5	278	3.1	40.2
"	2000	324	318	3.5	34.7

L-C in above chart are for a frequency of 14.1 mcs.
R-X Ohms, L microhenries C micro-microfarads.

Divide both L and C by 2 for 28.2 mcs.

Multiply both L and C by 2 for 7.05 mcs.

Multiply both L and C by 4 for 3.52 mcs.

As a starting point, tune the receiver to the exact frequency of the RF driving source used to excite the bridge. This should be done without any antenna or bridge connection to the receiver. The terminating line section of the bridge should then be connected to the receiver input terminals and the SWR noted on the bridge. Should the receiver input exactly match the impedance of the line the SWR will drop to unity if the line is looking into a purely resistive load. This may not necessarily be so in a receiver since it will depend upon whether the input circuit is in track at the particular frequency at which the measurement is being made. Two corrective measures are suggested: (1)-Disconnect the bridge and shunt the input terminals of the receiver with a carbon resistor then line up the RF trimmers for maximum output at the driving source frequency. (2)-Retune the receiver,(with the bridge connected as previously outlined) until a minimum value of SWR is indicated on the bridge meter. The reading obtained after either corrective measure will give a reasonable approximation of the degree of mismatch and the amount by which the receiver input impedance varies from the impedance of the transmission line used between bridge and receiver. This line impedance should of course be identical to that of the line used with the regular antenna. In general, the receiver input impedance will be higher than a 52 ohm line and an approximation as to the true input impedance may be obtained by multiplying the line impedance by the SWR obtained in the measuring procedure outlined. Knowing the input impedance of the receiver and the line impedance, a network can be designed to accomplish the necessary impedance transformation.

It is significant to note that matching networks containing reactive elements will provide an exact match at only a single frequency without readjustment. Since it is inconvenient to have to change the network tuning as the receiver is tuned it is advisable to select a measuring frequency at the mid-point of the normal operating band. Even though the network departs from exact match,the consequent degree of mis-match is small particularly over the relatively narrow amateur bands. It will certainly be far less at its worst than many receivers without networks are at their best.

The "L" is one of the most simple configurations for a matching network. It has only two reactive elements, a coil and a capacitor which makes it comparatively simple in both design and adjustment. The accompanying chart has been worked out for a line impedance of 52 ohms into a number of different possible receiver impedances at a frequency of 14.1 mc. The values given are to slide rule accuracy but variations must be expected in both elements since the inductance of the receiver primary winding may cause various effects.

When appropriate values of L-C have been selected from the chart and connected as shown in the accompanying diagram, the original measuring procedure using the co-ax bridge should be repeated except that the network is now connected between the co-ax bridge output and the receiver input terminals. (leads from the network to the receiver must be short--two inches at most) The network variable capacitor should now be adjusted for a minimum SWR on the bridge. Assuming that one has started out with a coil that has more turns than would eventually be used--short out one turn then retune the capacitor for a new minimum SWR. Keep shorting out turns and retuning the capacitor until the SWR drops to unity. If the SWR assumes higher value when the inductance of the coil is decreased a larger coil is indicated. This is assuming of course that a satisfactorily low SWR is not obtained with the original inductance as-is...a happy but very unlikely condition. As stated, the SWR will never approach unity if the receiver input is reactive thus make sure that the receiver tuning dial is adjusted for a minimum SWR even though the tuning may be such that the signal can no longer be heard. If the receiver has an external antenna trimmer it should be possible to set the receiver dial to the exact source frequency and bring the SWR to minimum by adjustment of this trimmer control.

An L network has two interdependent elements which must bear a definite relation to each other if the network is to function properly. In theory, the shunting capacitive arm establishes the impedance transformation...the series inductor simply acts to cancel out the capacitive reactance introduced. If the impedance ratio is fairly high, (perhaps a ratio of 52 to 500 ohms) the reactances in the two arms will approach the same value thereby indicating that the combination is nearly resonant at the design frequency. In such cases, "C" might be tentatively established by using a variable capacitor of the straight-line-capacity, (semi-circular plate) type whose minimum and maximum capacity values are known. The capacity will then be roughly proportionate to the angular engagement of the rotor and stator. The equivalent inductance might then be approximated by adjusting the coil to resonance with the known capacitor at the design frequency. In any case, try to start out with a coil that has too many turns....it being far easier to take off or to short out turns than it would be to add them.

In summary, it should be stated that an L network can be designed from formula that will eliminate cut-and-try if the input and output loads are pure resistances. In practice, the necessity for juggling network elements is due to the fact that neither the line nor the receiver input are necessarily pure resistances.

Formulas and design data used in this paper may be found in COMMUNICATION ENGINEERING by W.L.Everitt and RADIO ENGINEERS' HANDBOOK by F.E.Terman. Both published by Mc Graw-Hill Book Company, New York.

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